THE UV-VIS OPTICAL ENVIRONMENT OF THE SHUTTLE

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Abstract. During the Spacelab 1 shuttle mission, spectroscopic measurements were made of the atmospheric emissions over a broad wavelength range extending from the extreme ultraviolet to the near infrared. These measurements were made under a variety of vehicle attitude and sunlight conditions. Superimposed on such spectra would be any features associated with the induced vehicle environment and its interaction with solar photons and the ambient neutral atmosphere and plasma. In this paper, we discuss various anomalies and unexpected features in the spectra from the perspective of possible shuttle-induced origins. The data indicate a dramatic cleanup of the vehicle environment over the course of the 10-day mission, a strong non-atmospheric red continuum underlying the spectra at night and at large angles to the velocity vector, and a variety of molecular band distributions which are not explained by our present understanding of the atmopshere.

Introduction

The phenomenon of glows associated with spacecraft surfaces directed into the velocity vector is now widely known. In the case of the shuttle at altitudes near 250 km, these glows are visible to the naked eye at night and are readily photographed with hand-held cameras [see Banks et al., 1983; Mende et al., 1983]. In addition, it has been recognized for many years that sensitive instruments directed into the velocity vector experience an intensity enhancement that increases significantly from the blue to the red and which is due to the interaction of the vehicle with the ambient environment [Torr et al., 1977; Yee and Abreu, 1983]. These effects are well covered in related papers in these proceedings.

Of major concern to those working at low light levels from space vehicles is whether these effects are due entirely to surface and near surface glow which can perhaps be avoided by looking at angles other than the ram or by operating at much greater altitudes, or whether an extended optical contamination exists around the vehicle. A clear understanding of the extent of the induced optical environment is of importance to investigations from space shuttle, Space Station, Space Telescope, and vehicles operating in the upper atmosphere in general.

At the First Shuttle Glow Workshop a year ago, we reported an initial data set obtained on the Spacelab 1 shuttle flight with the Imaging Spectrometric Observatory (ISO). These particular data were obtained in an observing sequence in which the field-of-view was directed tangentially away from the Earth and straight out of the payload bay (-Z axis) into the velocity vector. The data were acquired on the dayside of the Earth. From these data it was concluded that the wavelength region from 6000 Å to 8000 Å was densely populated with a number of bright overlapped bands. These bands were subsequently tentatively identified as N_2(1P) [Torr and Torr, 1985a] and were found to significantly exceed the brightness of these features expected from the ambient atmosphere.

It then becomes of obvious interest to know how these spectra obtained looking into the velocity vector compare with others obtained with different viewing geometries and under different conditions of solar illumination. In the following sections, we present a variety of preliminary spectra obtained in different orientations.

Results

Three spectra are shown in Figure 1, all taken with the field-of-view of the instrument looking tangentially away from the Earth and on the dayside, but with the field-of-view into the wake, at 90° to the wake, and into the velocity vector, respectively. The lower panel (into the velocity vector) is the spectrum shown at the workshop a year ago. All three spectra show bright bands in the red. However, it should be noted that the scales on the three spectra are quite different, so that the intensities are increasingly bright going from the bottom to the top of the figure. Thus, the surprising aspect of the data shown in this figure is that the ram data are significantly "cleaner" in the red portion of the spectrum. The sensitivity of the instrument drops by a factor of 3 from 6000 Å to 8000 Å. Thus, there is a tendency to amplify the noise at higher wavelengths in converting from counts to R/Å. However, the integration periods are comparable in all three cases. The data taken with the field-of-view looking into the wake were taken on the first day of the mission, some 20 hours after launch. The data taken looking at 90° to the velocity vector were taken on the second day of the mission, approximately 40 hours after launch. The data into the velocity vector were acquired on day 10 of the mission and followed a very extended period of the payload bay being directed at the Sun (almost 24 hours). These results therefore suggest that there was a significant cleanup in the vehicle-induced environment over the course of the 10-day mission.

The data shown in Figure 2 were all taken looking at a tangent ray altitude of 250 km into the wake and on the first day of the mission. The comparison in this case is of different solar conditions; night, twilight, and day. In this case, relatively bright band features are again present in the red portion of the spectrum. Because so many of the contaminants are the same as the species occurring naturally in the atmosphere, the problem is to try to determine whether these features are due to the ambient upper atmosphere or due to the vehicle, or due to a distortion of the ambient environment by the vehicle. As was mentioned above, the viewing geometry in these three sequences is tangential to the Earth. In such a viewing configuration, naturally occurring features are considerably amplified because the slant path length of the atmosphere is longer than the vertical distance through the same emission layer. The slant path amplification factor at these altitudes would be approximately 30 for atmopsheric features. Thus, the features appearing in the nightglow spectrum would correspond to vertical intensities of 1-2 R/Å if they are of atmospheric origin. However, if the source is a glowing interaction region surrounding the vehicle, its intensity would not be expected to change in the same way with angle to the zenith.

In Figure 3, we show a comparison of the 250 km tangent ray altitude nighttime data shown in Figure 2, together with another nightglow spectrum taken with the field-of-view looking within 20° of the vertical.

The slant path factor difference in the obvious atmospheric features such as the $O(^1D)$ lines at 6300/6364 Å is evident. However, there is a major difference between the two spectra. We have been cautious in assigning any real significance to underlaying continuum in the ISO data from Spacelab 1 for various reasons. Our observing sequences were designed with relatively few background measurements and even some of these were lost due to launch delay impacts. In addition, the vehicle testing associated with the mission required subjecting the payload to thermal extremes. In several cases, there was the possibility that the nearest instrument background measurement might not fully remove a changing thermal background component. As a result, residual backgrounds were removed from the data and the analyses have concentrated on the line and band spectra. However, in the case of the near vertical spectrum shown in Figure 3, the continuum apparent in this spectrum was repeated on seven consecutive nightside passes, all of which had relatively good instrument background corrections. We therefore believe that these data (and possibly the other spectra shown also) indicate a strong red continuum with a peak intensity of approximately 30 R/Å. This continuum cannot be atmospheric in its origin and is observed at night looking at an angle of almost 90° to the velocity vector.

Figure 4 shows a dayglow spectral survey covering 600 Å to 8000 Å. In this case the instrument was looking at a tangent ray height of 150 km and at an angle of 20° to the wake. Six consecutive such spectra were obtained over a full orbit with the vehicle sunlit. Considerable analysis has yet to be done on these data and only a few comments will be made here. The red visible wavelengths are dominated by the bright O_2 atmospheric bands which are explained by atmospheric sources. The N_2(1P) bands in this region might also be explained by atmospheric processes. The N_2^+ emissions are anomalous and are discussed in another paper in these proceedings. Throughout the spectrum there are features for which we do not yet have identifications. The N_2 Lyman-Birge-Hopfield bands have a highly anomalous vibrational and rotational distribution (Figure 5). It is likely that this is an atmospheric phenomenon, but we do not yet understand the excitation mechanism [Torr and Torr, 1985b], and have found the same features, similarly anomalous, in the nightglow [Torr et al., 1985].

Conclusions

In this paper we have presented a number of spectra measured from Spacelab 1 under a variety of conditions. The data indicate a significant reduction of the intensity of features in the red portion of the spectrum over the course of the mission, which could be associated with a significant reduction in the vehicle outgassing over the 10 days of the mission. The nighttime data indicate a strong underlying red continuum (30 R/Å) at large angles to the velocity vector. The spectra in general show evidence of highly anomalous N_2 and N_2^+ band systems. At the present time we cannot account for these in terms of our current understanding of the atmospheric/ionospheric processes. In addition, the spectra contain a number of features which we cannot yet identify. Thus, either we do not understand some very fundamental aspects of the terrestrial atmosphere, or the shuttle environment comprises an extended interaction region in which various collision processes are occurring in large numbers.

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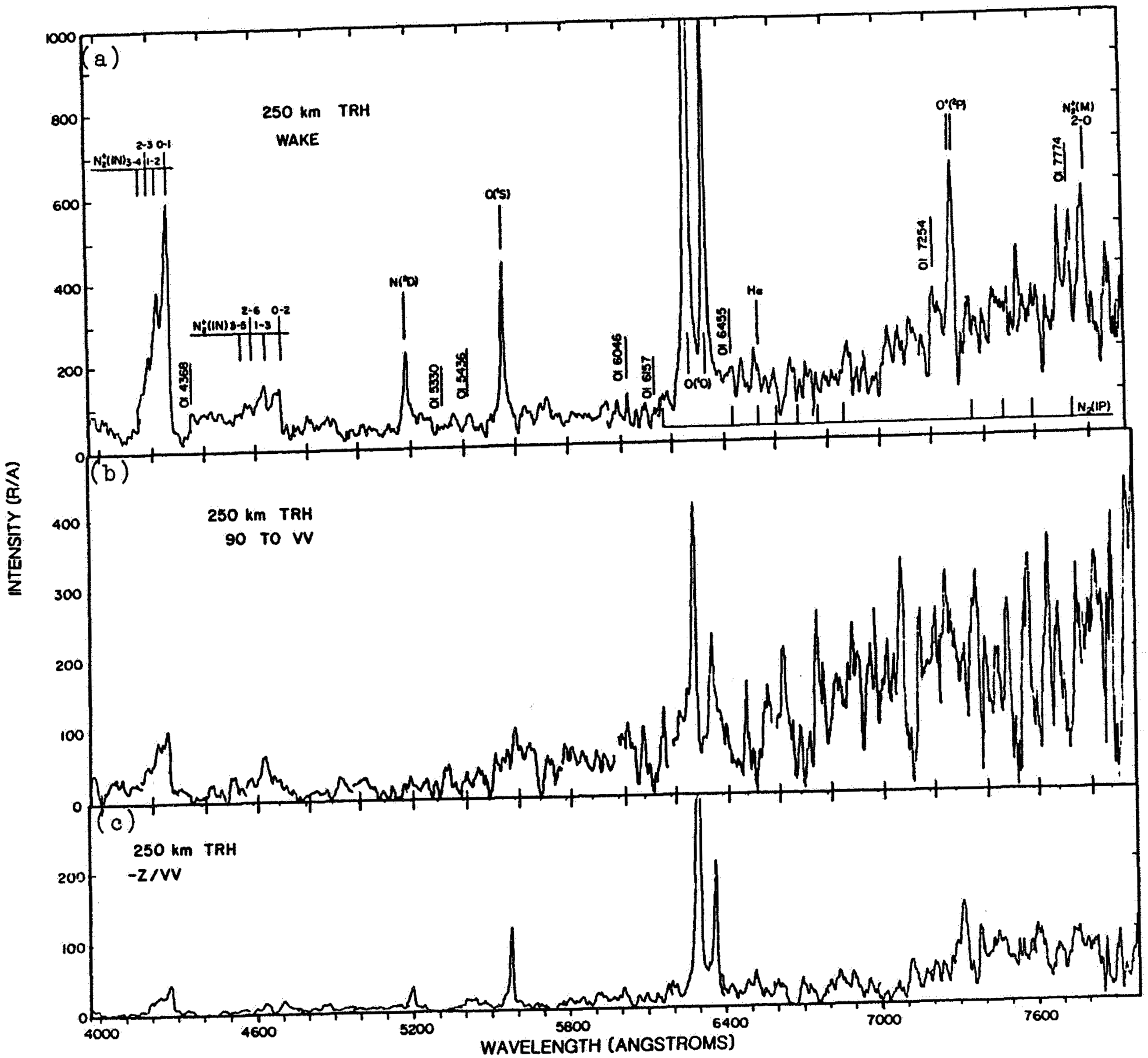

Fig. 1. Visible spectra taken on the sunlit side of the Earth with the field-of-view of the instrument looking (a) into the wake, (b) at 90^{o} to the wake and (c) into the velocity vector. In all cases the viewing geometry is tangentially away from the Earth at 250 km.

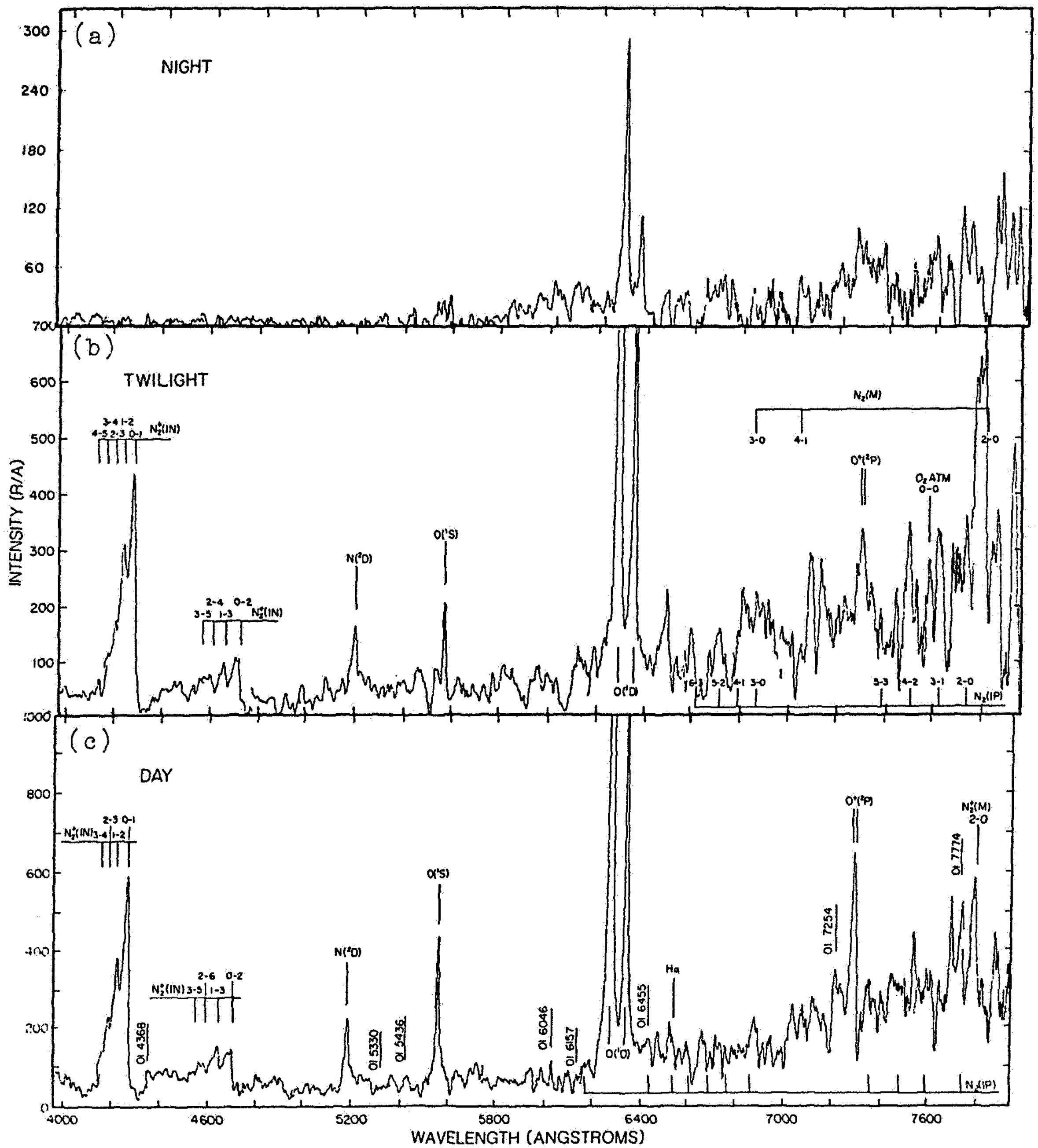

Fig. 2. Visible spectra looking into the wake (a) nightside, (b) twilight, and (c) dayside.

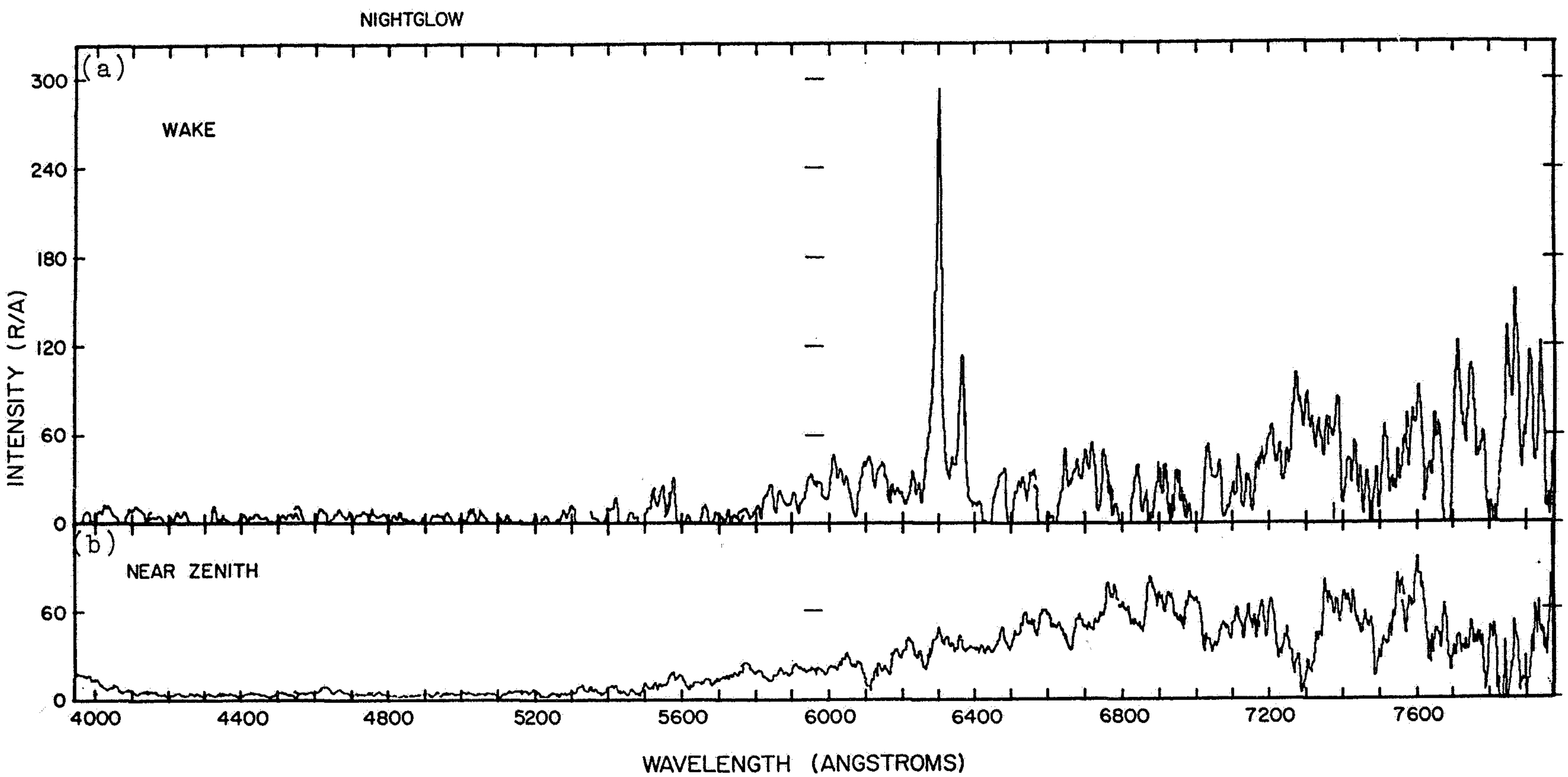

Fig. 3. Visible spectra taken on the nightside (a) looking at a 250 km tangent ray height (i.e., same spectrum as 2a) and (b) looking close to the vertical.

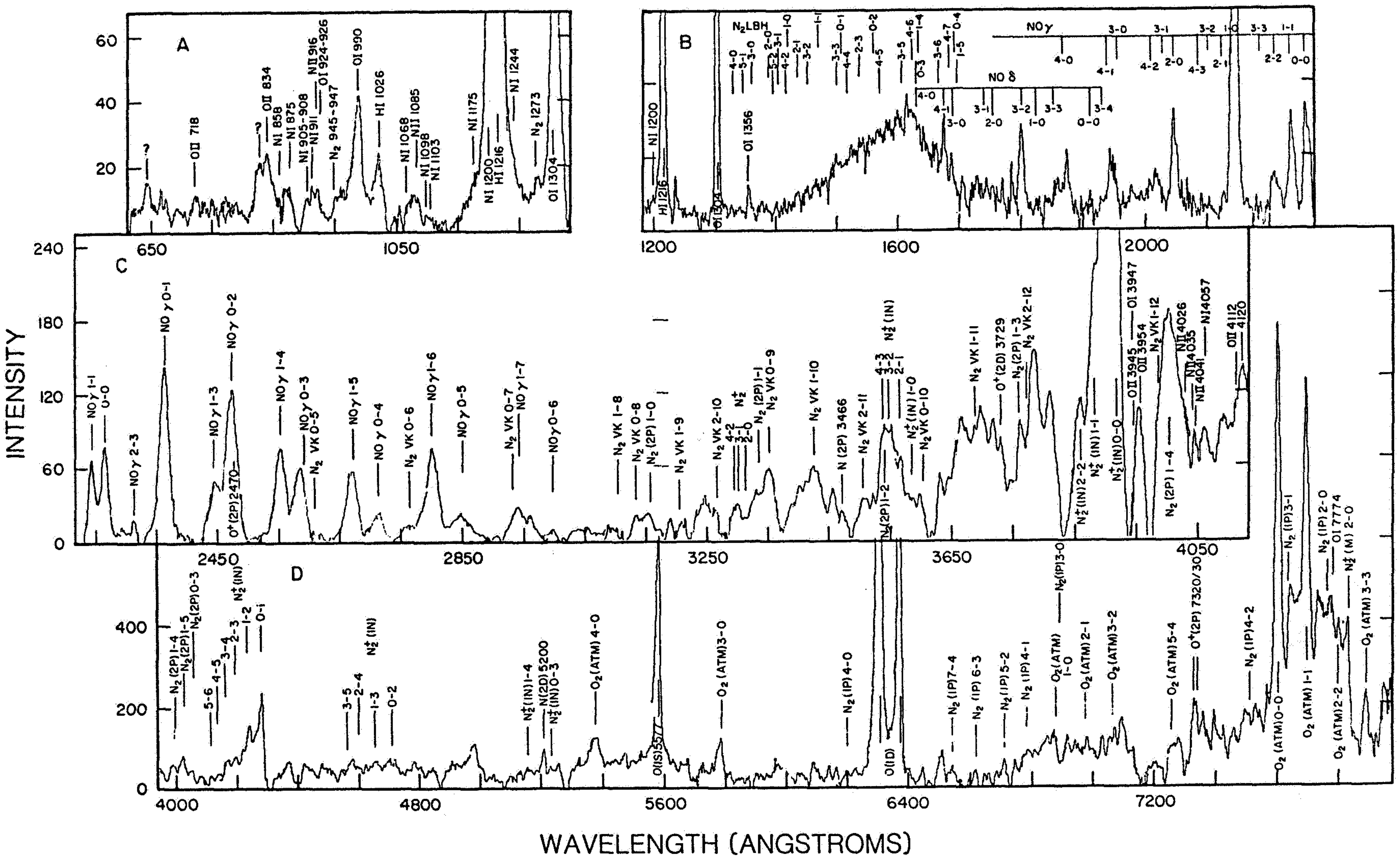

Fig. 4. Dayglow spectral survey for a 150 km tangent ray height. Intensity units are R/Å in all cases except for (a) the extreme ultraviolet wavelengths, in which case the units are counts/second [from Torr and Torr, 1985c].

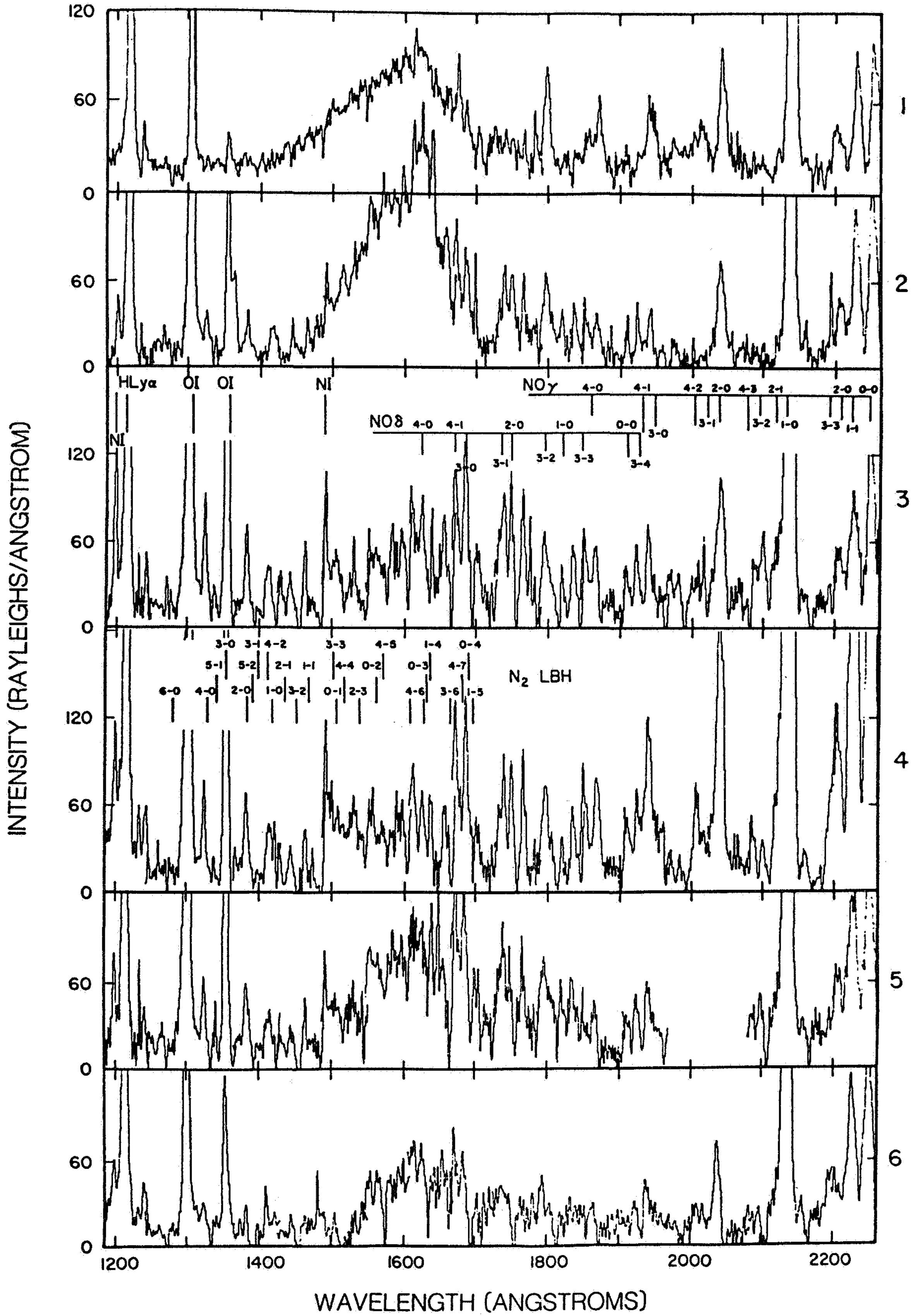

Fig. 5. Far ultraviolet spectra of the dayglow for a 150 km tangent ray height. The six consecutive spectra correspond to changing latitude and solar zenith angle conditions [from Torr and Torr, 1985b].